Appendix E

Dewatering Calculations

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MEMORANDUM

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TO:	Mike Byers	**CLIENT:**	BNSF, BN050-19390
FROM:	Cliff Baines, Stephen Howard	**TASK:**	Interim Action for Levee Cleanup
DATE:	2/21/06	**RE:**	Dewatering Modeling

Introduction

This memo is intended to document methods of fluid management within the excavation. It includes an additional estimate of the volume of water produced by dewatering to effect a negative hydraulic gradient into the excavation, methods to contain NAPL within the excavation and a brief summary of contingency actions to implement in the event that fluid from the excavation is migrating into the South Fork Skykomish River.

Description of the Remedial Action

The proposed interim action will consist of excavating petroleum-contaminated soil from beneath the flood control levee west of the 5th Street Bridge in Skykomish and from beneath adjacent portions of the South Fork Skykomish River to the north and the Town of Skykomish to the south. Excavation below the ordinary high water mark will be conducted within the regulatory fish window[1].

The base of the excavation will be below the water table for much of the duration of the excavation. In addition, the river level is expected to be higher than the undisturbed riverbed in the excavation area for most of the construction period. Inner and outer coffer dams will be installed on the river bed around the excavation in the river to protect the excavation from rises in the river level and to help prevent water from flowing out of the excavation and into the river. The total length of the coffer dam along the river is roughly 700 feet. Further details of the coffer dam construction are provided in the EDR. In addition, one to two interior north-south trending coffer dams will be placed across the interior of the excavation as described in the EDR to further reduce the anticipated volume of water pumped to maintain hydraulic control of the excavations.

The physical properties of the site have been described in the EDR and previous documents[2]. In addition, a recent soil and sediment investigation was conducted in the Skykomish River and the levee; details of this investigation are included in the EDR (Appendix B).

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[1] July 1 to September 15, 2006.
[2] The most comprehensive descriptions are included in the Supplemental Remedial Investigation Report (RETEC, 2001) and the Feasibility Study (RETEC, 2004).

Purpose of the Dewatering

Most of the excavation will probably be performed under wet conditions, however dewatering is proposed to create a hydraulic gradient towards the excavation pit and away from the river. An inward hydraulic gradient is required to keep water from the inside of the excavation from flowing through the subsurface under the coffer dams and into the river.

Groundwater Modeling to Estimate Dewatering Volumes

Groundwater flow modeling was conducted using SEEP2D. The model was constructed using known site characteristics and construction design drawings contained in the EDR.

Model Objective

The model objective was to estimate whether construction dewatering activities can maintain an inward gradient from the river without exceeding the maximum permitted surface water discharge rate (1,000 gpm). The model met the objective by calculating the volume of groundwater inflow into the planned excavation area for a given dewatering water elevation. The inflow volume was then directly compared to permit discharge limits.

Model Methods

Groundwater inflow was estimated using a computer software program called SEEP2D. SEEP2D is a two-dimensional steady state finite element groundwater flow program. The software program was developed by the US Army Corps of Engineers and is commonly applied to two-dimensional, cross sectional groundwater flow problems involving engineered structures such as dams, dikes, and sheet piles. These features can be modeled more efficiently and accurately using a finite element solution method rather than a finite difference solution method such as the one used in the software program MODFLOW.

Model Geometry

The model was constructed along the South-North cross-sectional line shown on Figure 1. This cross section line is located in the easternmost third of the excavation planned for the levee remediation. The cross section location was selected to represent a typical section of the excavation area. The basic model geometry is shown on Figure 2. The geometry is based on interpretation of engineering design drawings and ground surface/river bed topographic data.

The upland (south) boundary of the model is set at 200 feet south of the southern limit of the planned excavation area, approximately 30 feet north of with Railroad Avenue . The 200-foot distance represents the estimated distance where water table drawdown caused by excavation dewatering is zero. The northern model boundary is set in the middle portion of the Skykomish River where the riverbed has an elevation of approximately 914 feet above mean sea level (MSL).

The initial upper boundary of the model varies with location. Between the southern model boundary and the proposed southern limit of the excavation area the upper boundary drops uniformly between monitor well MW-37 (approximately 931 feet above mean sea level (ft-msl)) and the southern limit of the excavation area along the cross section line (approximately 926 ft-msl. The upper boundary then follows the surface slope of the excavation area to an elevation of 918 feet. The upper boundary remains at the 918 foot elevation until it intersects the coffer dams where the boundary follows the shape of the coffer dams with surface water in between the two dams. North of the coffer dams the upper boundary is a constant elevation of 919.1 feet, representing the assumed water level elevation in the Skykomish River.

The simulated model bottom represents an elevation of 855 feet, approximately 50 feet deeper than the deepest planned portion of the excavation area. This depth is probably great enough such that the depth of the model bottom will not affect the model results.

Model Mesh

The SEEP2D software program contains a finite element algorithm to solve groundwater flow equations. The algorithm uses a network of nodes and connecting lines known as a mesh to solve partial differential equations describing the flow of groundwater. The mesh can be modified to conform to the shape of geometric features. The density of nodes in the mesh can be varied to provide finer or coarser solutions to groundwater flow problems depending on the needs of the model. For example, the mesh at the excavation borders and near the excavation bottom is finer because finer meshes provide more accurate solutions to groundwater flow problems in areas of steep gradients or groundwater sinks and sources. Conversely, the mesh is coarser in areas further from and deeper beneath the excavation area because the accuracy of the solution is not affected by the mesh density in these areas. The initially constructed mesh is shown on Figure 3.

As previously discussed the mesh can be modified to conform to the shape of geometric features. This feature of the finite element method conforms to the shape of the mesh boundaries to the slope of the water table calculated by the model. The conforming of the mesh to the water table surface occurs when the water table is modeled as unconfined. The conformed mesh is automatically calculated by the model. The groundwater flow system in the excavation area is modeled as unconfined, consistent with the current site conceptual model. The water table modified mesh is shown on Figure 4.

Material Properties and Boundary Conditions

Three material properties are specified in the model. These three properties represent native alluvium, sheet piles/coffer dam, and surface water. Native alluvium is assigned a uniform isotropic hydraulic conductivity value of 64 feet per day[3]. Although actual native alluvium stratigraphy and corresponding material properties are variable, the native alluvium was assigned

[3] This hydraulic conductivity is the average hydraulic conductivity determined from slug tests performed in the upland sand and gravel. Further details are included in the Supplemental Remedial Investigation Report (RETEC, 2001).

a uniform hydraulic conductivity value to simplify the modeling process and maintain flexibility for any future modeling. Sheet piles and the coffer dam are assigned hydraulic conductivity values of 0.1 feet per day. Sheet pile and coffer dam locations are shown on Figures 1 and 2.

Surface water areas are simulated by assigning a hydraulic conductivity value of 10,000 feet per day. This value creates negligible resistance to groundwater flow and facilitates the simulation of surface water using the finite element method. Three areas of surface water are simulated: the area between the northern model boundary to the northern-most coffer dam, the area between the two coffer dams, and the area between the southern-most coffer dam and the planned location of the temporary sheet pile wall.

The southern (upland) model boundary is simulated as a constant head boundary with a value of 922.15 feet. This value is the average water level elevation near July 1 between the years 2002 and 2005 at monitor well MW-37, located on Railroad Avenue. The boundary condition assumes no vertical component to the groundwater flow gradient at MW-37. The northern model boundary is simulated as a constant head boundary with a value of 919.1, the mean river stage elevation during July 2000. The 919.1 foot value is also assigned to all upper boundary nodes north of the coffer dams. Upper boundary nodes between the coffer dams and the sheet pile are assigned a constant head value of 918 feet. The 918 foot elevation represents a head potential difference of about 1 foot between the river and the excavation area.

Six sheet pile and south excavation wall boundary nodes at elevations between 918 and 922.15 feet are assigned as exit face nodes. The exit face nodes allow the model to calculate the configuration of the water table across the plane of the sheet pile.

Model Results

The SEEP2D program software automatically calculates the net flow of groundwater through the model. In the model domain described in this memo, groundwater enters and exits the model through constant head nodes. Nodes where groundwater enters the model include the southern and northern boundary nodes as well as the upper boundary constant head nodes north of the coffer dams. Groundwater exits the model through all 918 foot constant head nodes, simulating pumping from the interior of the excavation necessary to maintain a 1 foot head difference across the coffer dams. Model calculated groundwater elevation contours and flow lines are shown on Figure 5. Most of the groundwater flowing into the excavation area comes from the river.

The net flow calculated by the model is about 0.9 gallons per minute per linear foot of excavation parallel to the river. The estimated flow rate is the combined flow of groundwater flowing into the excavation area from the south (upland) and the north (the river). The 0.9 gallons per minute flow rate represents the flow rate of water required to be removed from the excavation area to maintain a constant head elevation of 918 feet. This volume does not account for groundwater inflow across the western and eastern excavation boundaries. However, based on preliminary model results, this volume is less than 0.5 gallons per minute per foot of distance along the north/south sides. Therefore, to maintain hydraulic control over the entire excavation area (700 lineal feet east/west and the east and west ends), a pumping rate of around 930 gallons per minute (gpm) is predicted. To maintain control over a smaller excavation that would be the result of placing a single interior cofferdam, a pumping rate slightly over 600 gpm is predicted. For the scenario of utilization of two interior cofferdams, the excavation size is approximately 230 in the east-west direction and 300 feet in the north-south direction, and the predicted pumping rate to maintain the one foot head difference across the cofferdam is slightly greater than 500 gpm.

Model Sensitivity

The model was constructed using engineering design documents, historic groundwater and surface water elevations, and existing knowledge of site characteristics. Parameters that could be varied to evaluate their affect on calculated discharge rates include constant head values, hydraulic conductivity values, and the geometry of the excavation area.

If constant head values are not changed, there will be a direct linear correlation between a change in hydraulic conductivity and a change in groundwater flow rate. This correlation is more important if the modeled hydraulic conductivity is increased rather than decreased. However, hydraulic conductivity would have to be increased approximately three times to create groundwater flow rates that may be greater than what ordinary dewatering measures can accommodate. This is unrealistic given the nature of the sediments present in the excavation area.

Sensitivity analysis for the modeling described in this memo consists of varying the geometry of the excavation area, and the associated constant head node values. The first sensitivity analysis scenario simulates dewatering to an elevation of 916 feet-msl within an open excavation (i.e an approximate drawdown of 3 feet). The model calculated flow based on this scenario is about 1.9 gpm per linear foot of excavation parallel to the river. The second sensitivity scenario simulates dewatering to an elevation of 910 feet-msl within an open excavation (i.e. an approximate drawdown of nine feet). The model calculated flow for the second sensitivity scenario is 3.4 gpm per linear foot of excavation parallel to the river.

A third sensitivity scenario simulates an upland constant head of 924.15, two feet greater than the original constant head boundary value of 922.15. The 924.15 head value is 1 foot greater than the highest documented summer-time water level at well MW-37. The model predicted groundwater inflow rate for this scenario is 1.1 gpm, about 0.2 gpm greater than the initial model configuration.

Changing the constant head value of the river will not affect the simulated flow rates because in practice the dewatering heads in the excavation area will be adjusted to maintain a minimum head differential required to maintain flow from the river toward the excavation area.

NAPL Control

Diesel and Bunker C will be excavated during the cleanup action. Since some of this will be present as NAPL in soil beneath the water table, it is probable that free-phase petroleum hydrocarbons (NAPL) will be released into the excavation during the remedial activities. The

NAPL will potentially be present as a layer floating on the water surface as well as a lesser volume in small discrete bodies beneath the water table. Water will be present within the excavation; therefore, engineering measures will be taken to ensure that NAPL does not spread across the entire water surface in the excavation. These measures will include the following:

Booms

Booms will be placed around the inside of the coffer dam, these boom will consist of booms with skirts of oil-absorbent material. This type of boom should be effective at controlling the spread of oil across the water surface as will as preventing oil from passing beneath the boom.

A line of booms will also be emplaced outside the coffer dams for added assurance that small releases of NAPL be captured before they flow down the Skykomish River.

Skimmer pumps

Skimmer pumps will be employed inside the booms to remove oil from the water in the excavation, and to reduce the probability of oil escaping the booms. In addition, skimmer pumps will be used throughout the excavation as required to reduce the migration of NAPL across the excavation pit.

Absorbent Pads

Oil absorbent pads will be used as necessary to remove floating oil from the excavation. These will be used to remove oil from heavy seeps and to contain the oil closer to the excavation face. They may also be used behind the booms, as required.

Contingencies

Contingency measures will be available to prevent the migration of oil and reduce the possibility that contaminants are released into the Skykomish River. These measures may be used if the dewatering pumps are ineffective in containing fluids (especially NAPL) within the excavation or if the coffer dam is breached by flood waters.

The effectiveness of the dewatering system at maintaining flow into the excavation will be monitored by collecting frequent measurements of the water levels around the outer perimeter of the coffer dams (in the Skykomish River) and within the excavation pit, using automatic water level data loggers. These water level data will be supplemented by visual observations looking for the presence of sheen or some other indication of contamination outside the coffer dams. If the monitoring indicates that the dewatering system is ineffective, contingency measures will be undertaken. These will consist of additional containment of NAPL within the excavation pit by use of additional booms, adsorbent pads and skimmer pumps.

Two coffer dams will be constructed on the river bed around the excavation area. The second coffer dam will be constructed as a contingency measure to protect the river if the outer dam fails. These coffer dams will be lined with impermeable flexible sheeting to prevent excavation water from seeping into the river through the dams. As described in the EDR, should a breach in either coffer dam occur, work will immediately stop and measures will be taken to repair the dam. The on-call Spill Response contractor will be called in as needed to recover any substances that have accidentally been released.

In addition to the two coffer dams, an outer line of booms will be emplaced outside the coffer dams for added assurance that small releases of NAPL are captured before they flow down the Skykomish River.

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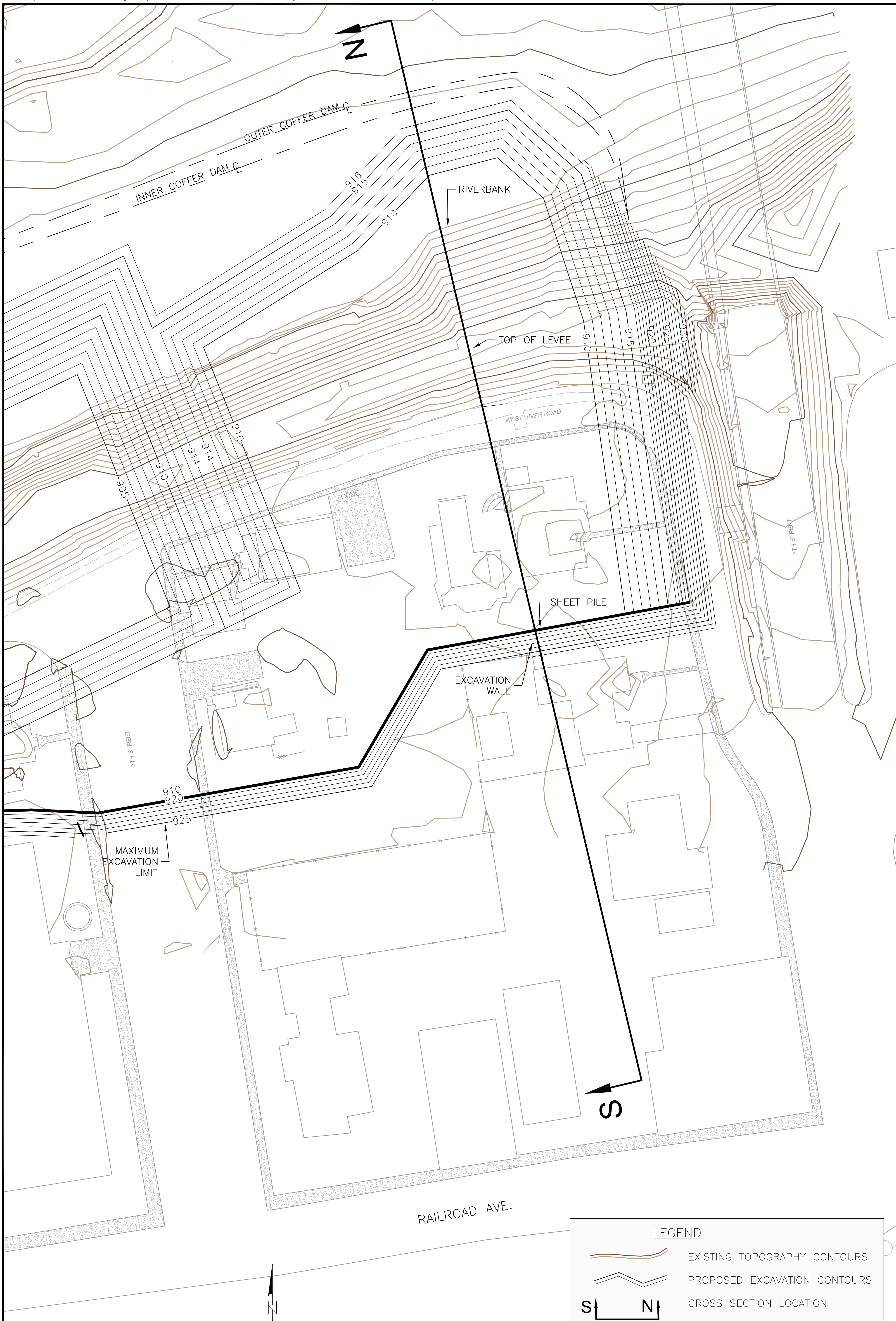

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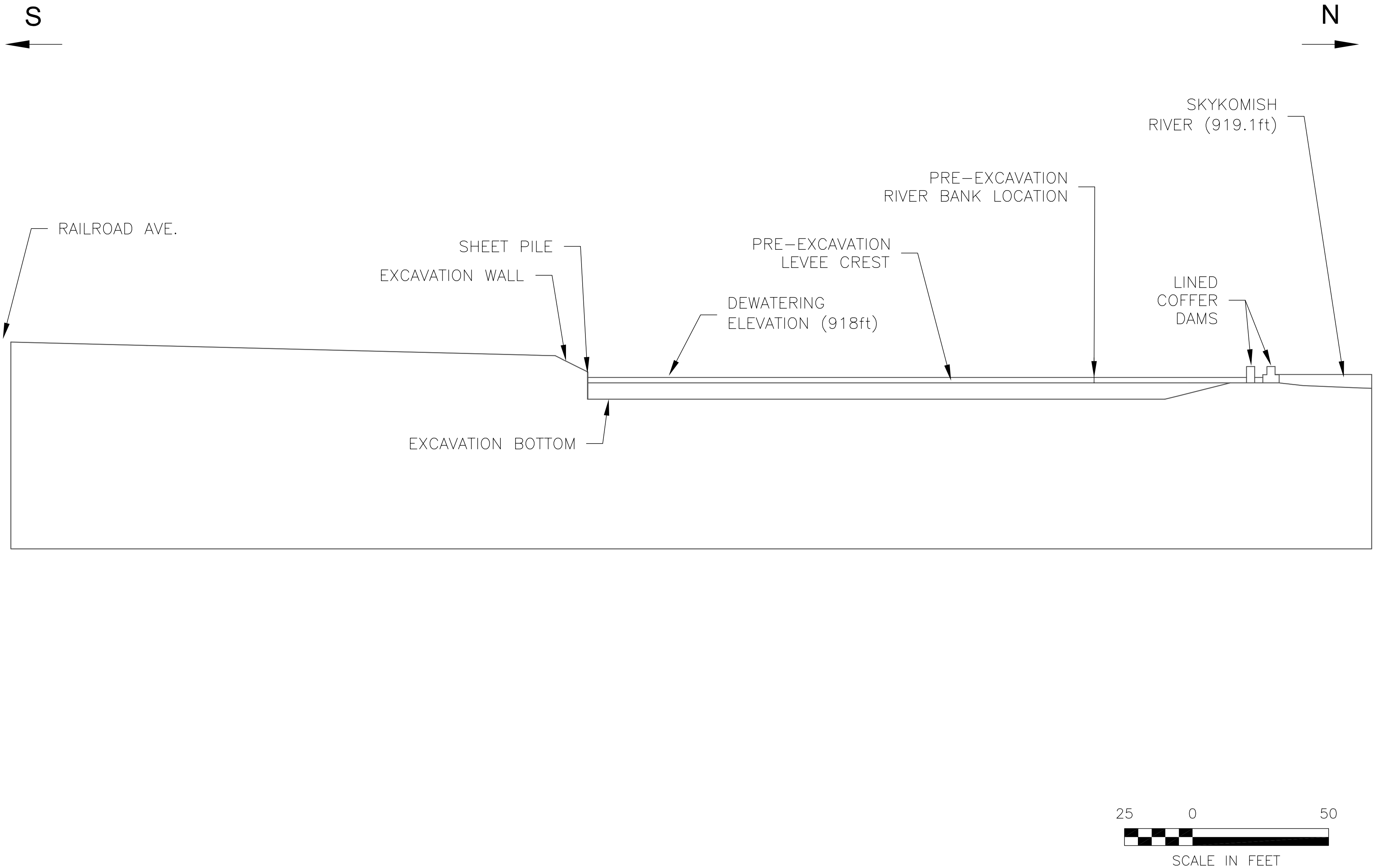
DATE: 02/20/06 DRWN: A.S./SEA

CROSS-SECTION MODEL LOCATION

FIGURE 1



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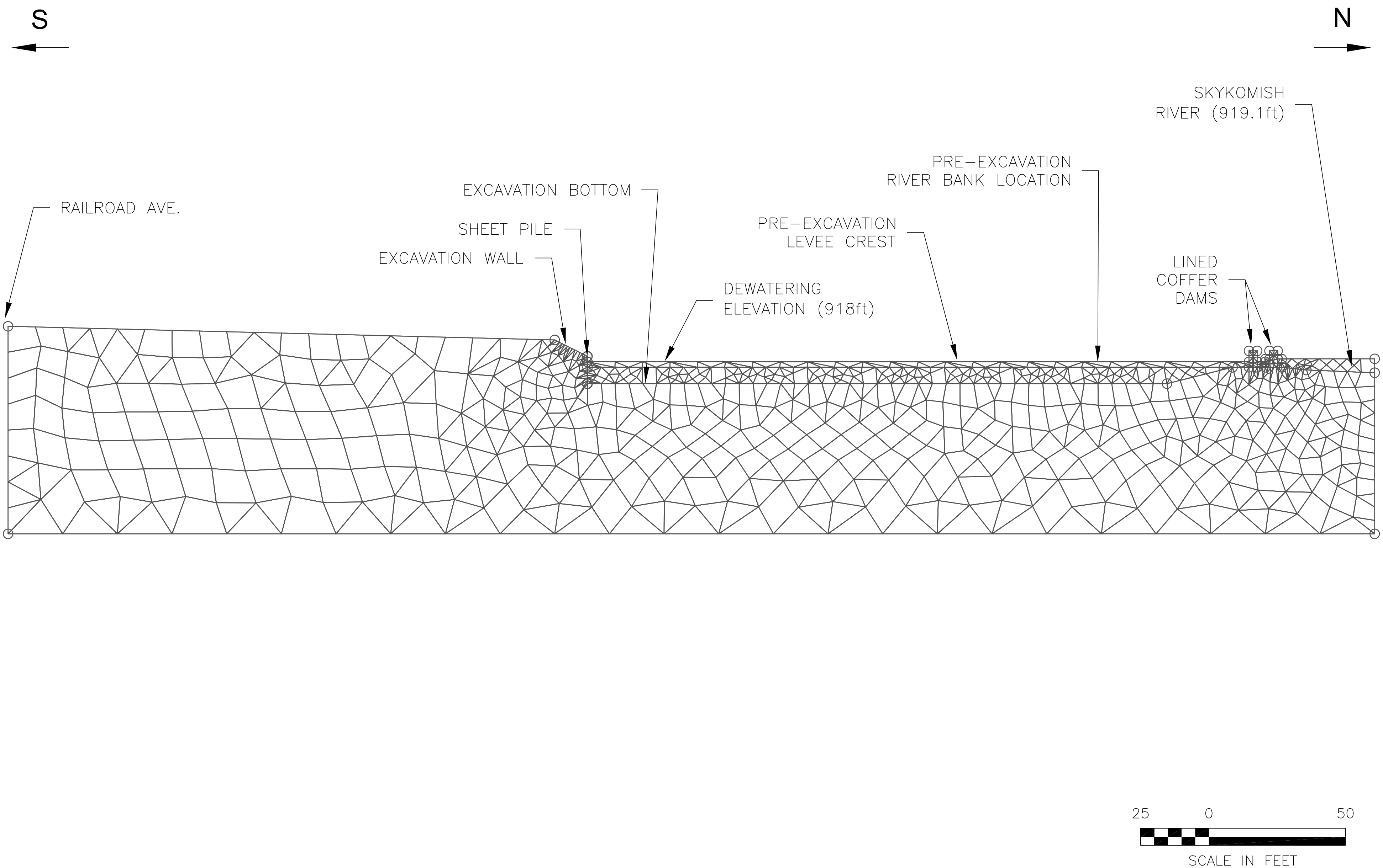
BASIC GEOMETRY

DATE: 02/20/06	DRWN: A.S./SEA		**FIGURE 2**

File: H:\16423\EMAIL\FROM CLIFF\Cell 1 N-S model mesh.dwg Layout: ANSI_AI-CP User: astenberg Plotted: Feb 21, 2006 - 3:59pm Xref's:



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INITIAL MODEL MESH

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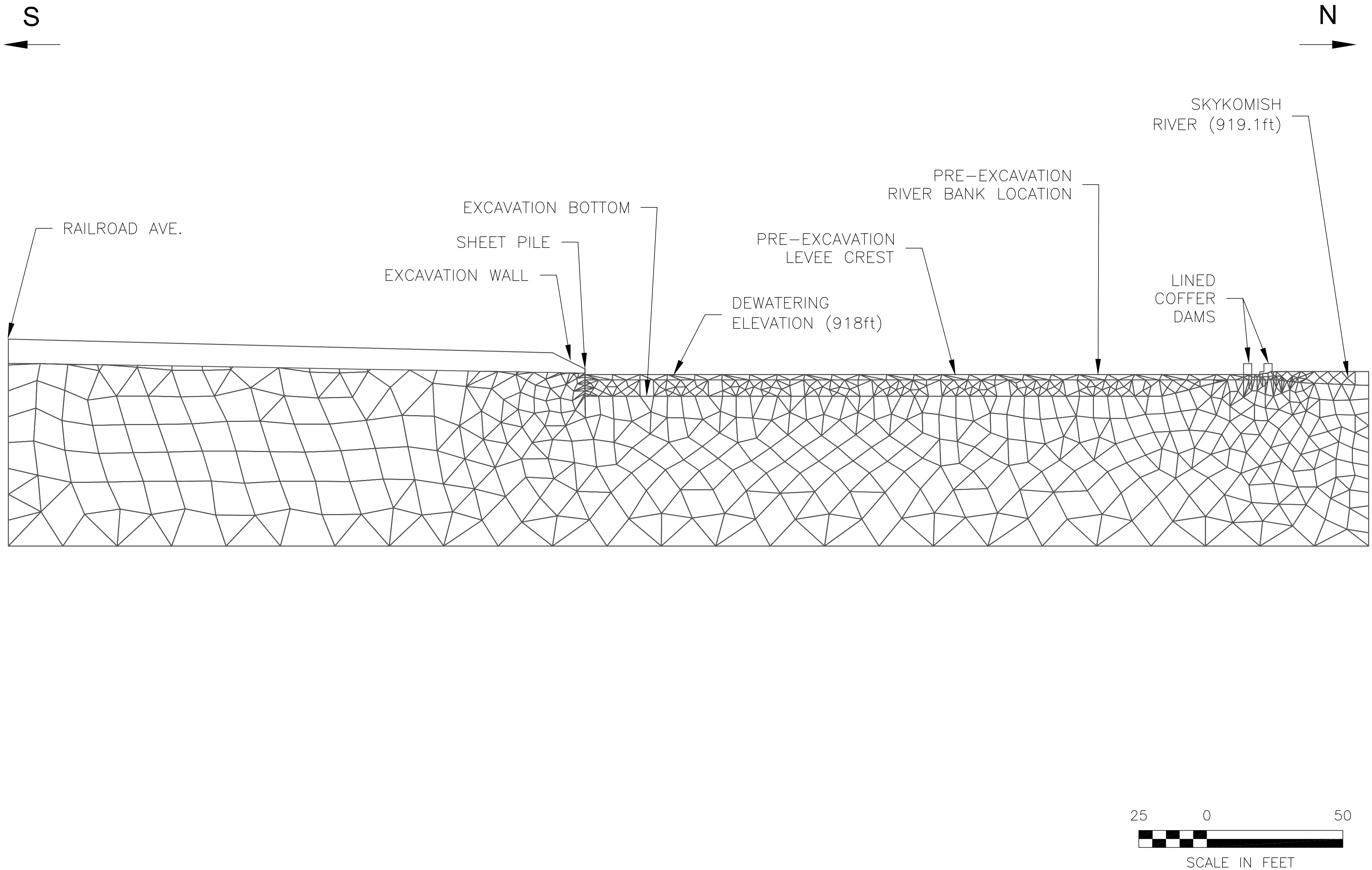
FIGURE 3

File: H:\16423\EMAIL\FROM CLIFF\Cell 1 N-S model mesh WT.dwg Layout: ANSI_AI-CP User: astenberg Plotted: Feb 21, 2006 - 3:58pm Xref's:



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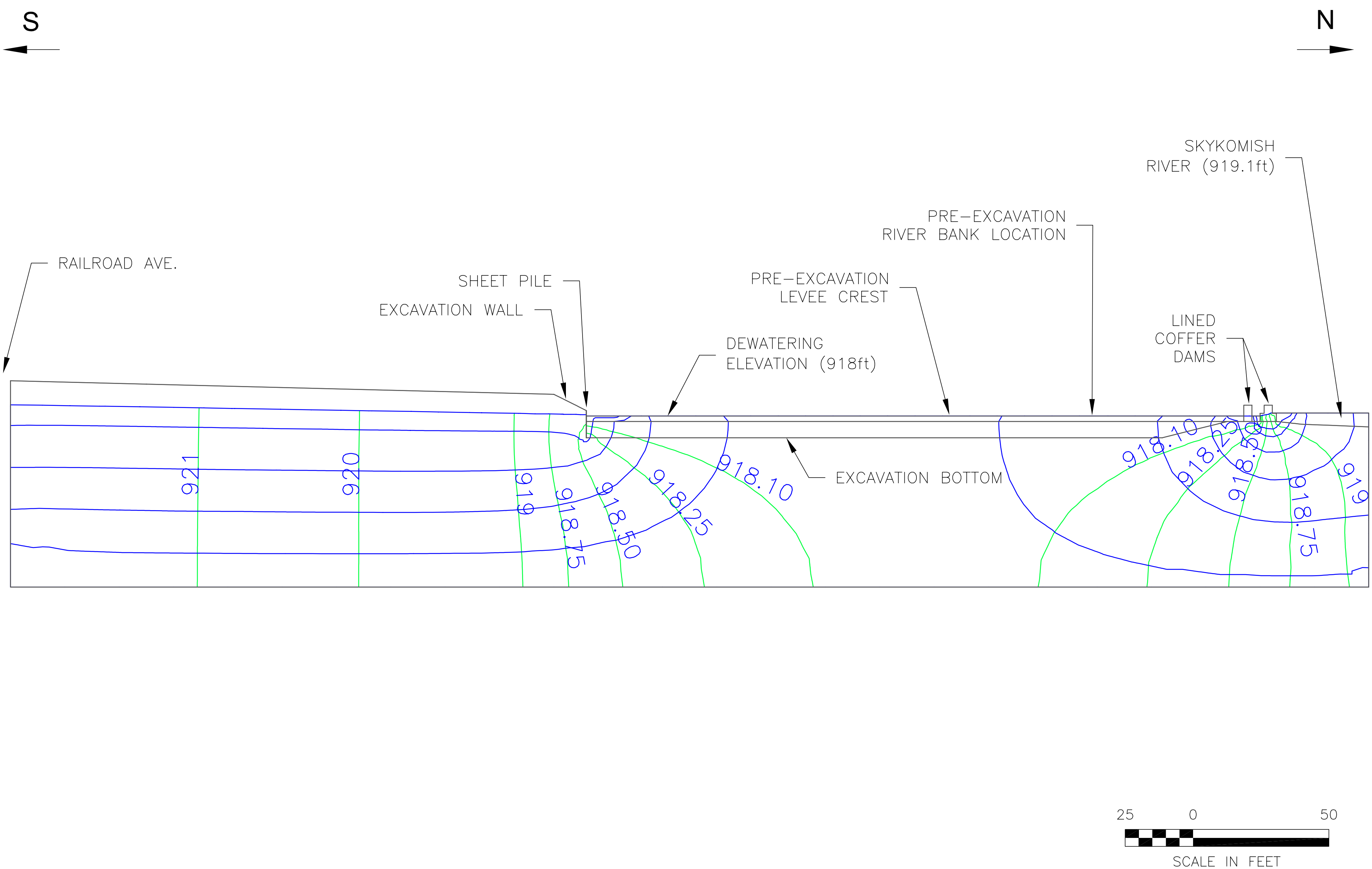
MODIFIED MODEL MESH

DATE: 02/20/06	DRWN: A.S./SEA		**FIGURE 4**



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MODEL PREDICTED GROUNDWATER FLOW LINES AND CONTOURS

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FIGURE 5